(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 648 010 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **94202866.3**

(22) Date of filing: **04.10.94**

(51) Int. Cl.⁶: H03F 1/08, H03F 3/45

(30) Priority: **11.10.93 BE 9301066**

(43) Date of publication of application: **12.04.95 Bulletin 95/15**

(84) Designated Contracting States: **DE FR GB IT NL**

(71) Applicant: **PHILIPS ELECTRONICS N.V.**
Groenewoudseweg 1
NL-5621 BA Eindhoven (NL)

(72) Inventor: **Pothast, Hendrik Jan**
c/o Int. Octrooibureau B.V.,
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)
Inventor: **Voorman, Johannes Otto**
c/o Int. Octrooibureau B.V.,
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

(74) Representative: **Schoonheijm, Harry Barend et al**
INTERNATIONAAL OCTROOIBUREAU B.V.,
Prof.Holstlaan 6
NL-5656 AA Eindhoven (NL)

(54) Frequency compensation circuit for stabilising a differential amplifier with cross-coupled transistors.

(57) A differential amplifier comprises a Darlington differential pair (T_1/T_3, T_2/T_4) and a cross-coupled transistor pair (T_5, T_6) to increase the transconductance of the Darlington differential pair (T_1/T_3, T_2/T_4). The negative input impedance of the differential amplifier as a result of the presence of the cross-coupled differential pair (T_5, T_6) is compensated for at high frequencies and the gain of the differential amplifier is reduced by a compensation circuit with a capacitor (30) between the control electrodes of the transistors of the cross-coupled differential pair (T_5, T_6) and with resistors (26, 28) in series with the control electrodes of the transistors of the cross-coupled differential pair (T_5, T_6).

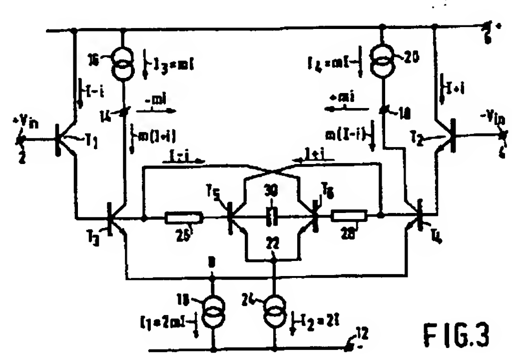


FIG.3

EP 0 648 010 A1

The invention relates to a differential amplifier for amplifying an input signal to an output signal, comprising:

- a first input terminal and a second input terminal for receiving the input signal,
- a first output terminal and a second output terminal for supplying the output signal,
- a first transistor and a second transistor, each having a first main electrode, a second main electrode and a control electrode, the control electrode of the first transistor being connected to the first input terminal and the control electrode of the second transistor being connected to the second input terminal;
- a third transistor and a fourth transistor, each having a first main electrode, a second main electrode and a control electrode, the control electrode of the third transistor being connected to the first main electrode of the first transistor and the control electrode of the fourth transistor being connected to the first main electrode of the second transistor; the first main electrode of the third transistor and the first main electrode of the fourth transistor being connected to a first node to receive a bias current, and the second main electrode of the third transistor being coupled to the first output terminal and the second main electrode of the fourth transistor being coupled to the second output terminal,
- a fifth transistor and a sixth transistor, each having a first main electrode, a second main electrode and a control electrode, the control electrode of the fifth transistor being connected to the first main electrode of the first transistor and the control electrode of the sixth transistor being connected to the first main electrode of the second transistor; the first main electrode of the fifth transistor and the first main electrode of the sixth transistor being connected to a second node to receive a bias current; the second main electrode of the fifth transistor being connected to the first main electrode of the second transistor and the second main electrode of the sixth transistor being connected to the first main electrode of the first transistor.

Such a differential amplifier is known from Netherlands Patent Application no. 8602892, published on June 1st, 1988. Differential amplifiers of this type are also referred to as transconductors and are used *inter alia* in continuous-time balanced integrator filters for various purposes, such as video filters, equalizers etc. This requires differential amplifiers having a large gain-bandwidth product. Preferably, single-stage differential amplifiers are used in order to obtain a large bandwidth in conjunction with a low supply current. Figure 1 shows the differential amplifier in accordance with said Netherlands Patent Application, which amplifier has a high gain and a large bandwidth owing to the cross-coupled fifth transistor T_5 and sixth transistor T_6. The cross-coupled transistors T_5 and T_6 provide positive feedback to reduce the conversion resistance of the first transistor T_1 and the second transistor T_2, as a result of which a large transconductance is obtained. However, a side-effect of the cross-coupled transistors is that the input impedance of the differential amplifier becomes negative. At low frequencies this effect is negligible but at high frequencies the filter circuit may become unstable as a result of additional phase shifts in the differential amplifier. A suitable compensation is required in order to suppress such instabilities. A conventional compensation method is illustrated in Fig. 2, which shows only a part of the differential amplifier. An RC series network having a positive impedance is arranged across the input terminals to neutralise the negative impedance of the differential amplifier at high frequencies. Although this known method is effective it reduces the high frequency gain and, consequently, the gain-bandwidth product.

It is an object of the invention to provide a compensation method so as to obtain a larger gain-bandwidth product.

According to the invention a differential amplifier of the type defined in the opening paragraph is therefore characterized in that the differential amplifier further comprises:

- a first resistor connected between the control electrode of the fifth transistor and the first main electrode of the first transistor,
- a second resistor connected between the control electrode of the sixth transistor and the first main electrode of the second transistor, and
- a capacitor connected between the control electrode of the fifth transistor and the control electrode of the sixth transistor.

The compensation circuit in accordance with the invention comprises the first and the second resistor and the capacitor, embedded in the topology of the cross-coupled differential amplifier. At low frequencies the compensation circuit does not affect the operation of the differential amplifier owing to the high impedance of the capacitor. The impedance of the capacitor decreases at increasing frequencies. The compensation circuit then increasingly reduces the effect of the cross-coupled transistors and eventually replaces these transistors effectively by two resistors arranged in series. The input impedanc of the cross-coupled differential amplifi r then becomes positive. The compensation method in accordance with the invention only affects th operation of th cross-coupled transistors.

The output transistors, *i.e.* the third transistor T_3 and the fourth transistor T_4, continue to provide the gain at high frequencies, in contradistinction to the known solution illustrated in Fig. 2, where at high frequencies the compensation circuit reduces the gain of the entire differential amplifier.

A further advantage of the compensation circuit in accordance with the invention in comparison with the known compensation method illustrated in Fig. 2 is that it requires a comparatively small chip area. A comparatively small time constant is attainable as a result of the gain from the first and the second input terminals of the differential amplifier to the control electrodes of the cross-coupled fifth and sixth transistors.

These and other features of the invention will be described and elucidated with reference to the accompanying drawings, in which

Figure 1 shows a known differential amplifier with cross-coupled transistors;

Figure 2 illustrates a known compensation technique for stabilising the differential amplifier shown in Figure 1;

Figure 3 shows a differential amplifier according to the invention with compensation in the cross-coupled transistors;

Figure 4 shows a first alternative embodiment of a differential amplifier in accordance with the invention;

Figure 5 shows a second alternative embodiment of a differential amplifier in accordance with the invention;

Figure 6 shows a third alternative embodiment of a differential amplifier in accordance with the invention;

Figure 7 shows a fourth alternative embodiment of a differential amplifier in accordance with the invention.

In the Figures parts or elements having the same function or purpose bear the same references.

Figure 3 shows a first embodiment of a compensated differential amplifier with bipolar transistors and with cross-coupled transistors in accordance with the invention. The differential amplifier comprises a first transistor T_1 having its control electrode or base connected to a first input terminal 2 and a second transistor T_2 having its base connected to a second input terminal 4. The second main electrode or collector of the first transistor T_1 and that of the second transistor T_2 are connected to a positive supply terminal 6. The differential amplifier further comprises a third transistor T_3 having its base connected to the first main electrode or emitter of the first transistor T_1, and a fourth transistor T_4 having its base connected to the emitter of the second transistor T_2. The emitters of the third transistor T_3 and the fourth transistor T_4 are connected to a first node 8, which is coupled to a negative supply terminal *via* a first current source 10. The first current source 10 supplies a bias current $I_1 = 2mI$ to the first node 8. The collector of the third transistor T_3 is connected to a first output terminal 14, which is coupled to the positive supply terminal 6 *via* a third current source 16. The collector of the fourth transistor T_4 is connected to a second output terminal 18, which is coupled to the positive supply terminal 6 *via* a fourth current source 20. The third current source 16 supplies a bias current $I_3 = mI$ and the fourth current source 20 also supplies a bias current $I_4 = mI$. The differential amplifier further comprises a fifth transistor T_5 having its collector connected to the emitter of the second transistor T_2, and a sixth transistor T_6 having its collector connected to the emitter of the first transistor T_1. The emitters of the fifth transistor T_5 and the sixth transistor T_6 are connected to a second node 22, which is coupled to the negative supply terminal *via* a second current source 24. The second current source 24 supplies a bias current $I_2 = 2I$ to the second node 22. The base of the fifth transistor T_5 is connected to the emitter of the first transistor T_1 *via* a first resistor 26. The base of the sixth transistor T_6 is connected to the emitter of the second transistor T_2 *via* a second resistor 28. A capacitor 30 is connected between the base of the fifth transistor T_5 and the base of the sixth transistor T_6.

The operation of the differential amplifier can be explained as follows. First of all, it is assumed that the first resistor 26 and the second resistor 28 have been short-circuited and that the capacitor 30 has been omitted. When a balanced input voltage $+V_{in}$ and $-V_{in}$ is applied to the input terminals 2 and 4, respectively, a current I-i will flow through the first transistor T_1 and a current I+i through the second transistor T_2, i being a signal current caused by the input voltage. The current I-i through the first transistor T_1 also flows through the sixth transistor T_6, and the current I+i through the second transistor T_2 also flows through the fifth transistor T_5. The magnitude of the signal current i is determined by the sum of the base-emitter resistances of the first transistor T_1, the second transistor T_2, the fifth transistor T_5 and the sixth transistor T_6. Since the signal currents through the first transistor T_1 and the fifth transistor T_5 and through the second transistor T_2 and the sixth transistor T_6 are opposed the emitter resistance of the first transistor T_1 is substantially compensated for by that of the fifth transistor T_5 and the emitter resistance of the second transistor T_2 is substantially compensated for by that of the sixth transistor T_6. The positive feedback of the cross-coupled fifth transistor T_5 and the sixth transistor T_6 makes the transconduc-

tance of the circuit comprising the first transistor T_1, the second transistor T_2, the fifth transistor T_5 and the sixth transistor T_6 very large. The third transistor T_3, the fourth transistor T_4, the fifth transistor T_5 and the sixth transistor T_6 form a translinear loop. In the case of equal emitter areas it follows from the well-known exponential relationship between the collector current and the base-emitter voltage of a bipolar transistor that the currents through the third transistor T_3 and the fifth transistor T_5 and the currents through the fourth transistor T_4 and the sixth transistor T_6 bear the same ratio to one another as the current I_1 of the first current source 10 and the current I_2 of the second current source 24. Consequently, the current flowing through the third transistor T_3 is m(I+i) and that through the fourth transistor T_4 is m(I-i). The d.c. component mI of the current through the third transistor T_3 is furnished by the third current source 16, so that a signal current -mi is available at the first output terminal 14. The d.c. component mI of the current through the fourth transistor T_4 is supplied by the fourth current source 20, so that a signal current + mi is available at the second output terminal 18.

The fifth transistor T_5 and the sixth transistor T_6 thus raise the transconductance of the differential pair comprising the first transistor T_1 and the second transistor T_2, whilst the differential pair comprising the third transistor T_3 and the fourth transistor T_4 provide additional current gain. The input impedance between the first input terminal 2 and the second input terminal 4 is negative. For a detailed analysis of the operation of the differential amplifier and for a calculation of the input impedance reference is made to United States Patent no. 4,476,440. At low frequencies the effect of the negative input impedance is negligible but at high frequencies a filter circuit comprising one or more differential amplifiers may become unstable as a result of additional phase shifts in the differential amplifier. A suitable compensation is necessary in order to suppress such instabilities. The compensation circuit comprises the first resistor 26, the second resistor 28 and the capacitor 30, which are embedded in the topology of the cross-coupled fifth transistor T_5 and the sixth transistor T_6. At low frequencies the compensation circuit does not affect the operation of the cross-coupled transistors owing to the high impedance of the capacitor 30. The impedance of the capacitor 30 decreases at increasing frequencies. The compensation circuit then increasingly reduces the effect of the cross-coupled transistors and eventually replaces these transistors effectively by the first resistor 26 and the second resistor 28 arranged in series. As a result of this, the input impedance of the cross-coupled differential amplifier becomes positive. The compensation method in accordanc with the invention affects virtually only the operation of the cross-coupled transistors. The output transistors, *i.e.* the third transistor T_3 and the fourth transistor T_4, continue to provide the gain at high frequencies, in contradistinction to the known solution illustrated in Fig. 2, where the compensation circuit reduces the gain of the entire differential amplifier at high frequencies.

A further advantage of the compensation circuit in accordance with the invention in comparison with the known compensation method illustrated in Fig. 2 is that it requires a comparatively small chip area. A comparatively small time constant is attainable as a result of the signal gain from the first input terminal 2 and the second input terminal 4 to the bases of the cross-coupled fifth transistor T_5 and sixth transistor T_6.

Fig. 4 shows the same differential amplifier as Fig. 3 but equipped with unipolar transistors, in which case the source, drain and gate perform the functions of the first main electrode, the second main electrode and the control electrode, respectively. In the present case insulated-gate MOS field-effect transistors are used but it is also possible to employ junction field-effect transistors (JFETs). The optional current source 32 between the source of the first transistor T_1 and the negative supply terminal 12 and the optional current source 34 between the source of the second transistor T_2 and the negative supply terminal preclude latch-up in the case of large input signals.

Figure 5 shows an alternative configuration of the differential amplifier. The differential amplifier shown in Fig. 3 has two separate current sources 10 and 24, whose currents I_1 and I_2 are in a ratio of m:1 in order to obtain a current gain m in the case of equal emitter areas of the third transistor T_3, the fourth transistor T_4, the fifth transistor T_5 and the sixth transistor T_6. In the differential amplifier shown in Fig. 5 said four transistors are operated by a common current source 36, which is connected both to the first node 8 and the second node 22 and which supplies a bias current I_5 = (2m+2)I. However, the emitter area of the third transistor T_3 and of the fourth transistor T_4 is now m times as large as the emitter area of the fifth transistor T_5 and the sixth transistor T_6. As a result of this, the currents through the third transistor T_3 and the fifth transistor T_5 and the currents through the fourth transistor T_4 and the sixth transistor T_6 again bear a ratio of m:1 to one another. Further, the operation is identical to that of the differential amplifier shown in Fig. 3. In the case of unipolar transistors the so-called W/L ratio of the relevant transistors instead of the emitter area should be scaled in similar proportions.

In order to obtain a comparatively high gain factor m the differential amplifier shown in Fig. 3 requires comparatively large emitter areas for the third transistor T_3 and the fourth transistor T_4. This problem can be avoided by means of the differential amplifier shown in Fig. 6, in which the third transistor T_3, the fourth transistor T_4, the fifth transistor T_5 and the sixth transistor T_6 have equal emitter areas. The first node 8 is now connected directly to the common current source 36 and the second node 22 is connected to this source *via* a third resistor 38. In order to achieve that the current through the third transistor T_3 and the fourth transistor T_4 are m times as large as the currents through the fifth transistor T_5 and the sixth transistor T_6 the difference between the base-emitter voltages of the third transistor T_3 and the fifth transistor T_5 and between the base-emitter voltages of the fourth transistor T_4 and the sixth transistor T_6 should be equal to $kT/q*\ln(m)$. For a current 2I through the third resistor this means that the resistance R of the third resistor 38 should be equal to $kT/(2qI)*\ln(m)$. The current density in the third transistor T_3 and in the fourth transistor T_4 is higher than in the differential amplifier shown in Fig. 5 and provides an improved high-frequency performance of the differential amplifier.

Fig. 7 shows an alternative configuration in which not only the second node is connected to the common current source 36 *via* the third resistor 38 but the first node 8 is also connected to said source *via* a fourth resistor 40. The common current source 36 is now constructed as a seventh transistor T_7 whose base is connected to a reference terminal 42, whose emitter is connected to the negative supply terminal 12 *via* resistor 44 and whose collector is connected to the third resistor 38 and the fourth resistor 40. The ratio between the currents through the third transistor T_3 and the fifth transistor T_5 and, consequently, between the currents through the fourth transistor T_4 and the sixth transistor T_6 is determined mainly by the ratio between the resistance values of the third resistor 38 and the fourth resistor 40. Since this resistance ratio can be selected freely it is also possible to realise almost any current gain factor m by means of the differential amplifier shown in Fig. 7.

In the same way as the differential amplifier shown in Fig. 3 the differential amplifiers shown in Figs. 5, 6 and 7 may also be equipped with unipolar MOS transistors or junction field-effect transistors (JFETs). Moreover, the bipolar and unipolar transistors shown herein may be replaced by transistors of opposite conductivity types, in which case the polarity of the power supply should be reversed.

Claims

1. A differential amplifier for amplifying an input signal to an output signal, comprising:
   - a first input terminal (2) and a second input terminal (4) for receiving the input signal,
   - a first output terminal (14) and a second output terminal (18) for supplying the output signal,
   - a first transistor (T_1) and a second transistor (T_2), each having a first main electrode, a second main electrode and a control electrode, the control electrode of the first transistor (T_1) being connected to the first input terminal (2) and the control electrode of the second transistor (T_2) being connected to the second input terminal (4);
   - a third transistor (T_3) and a fourth transistor (T_4), each having a first main electrode, a second main electrode and a control electrode, the control electrode of the third transistor (T_3) being connected to the first main electrode of the first transistor (T_1) and the control electrode of the fourth transistor (T_4) being connected to the first main electrode of the second transistor (T_2); the first main electrode of the third transistor (T_3) and the first main electrode of the fourth transistor (T_4) being connected to a first node (8) to receive a bias current, and the second main electrode of the third transistor (T_3) being coupled to the first output terminal (14) and the second main electrode of the fourth transistor (T_4) being coupled to the second output terminal (18),
   - a fifth transistor (T_5) and a sixth transistor (T_6), each having a first main electrode, a second main electrode and a control electrode, the control electrode of the fifth transistor (T_5) being connected to the first main electrode of the first transistor (T_1) and the control electrode of the sixth transistor (T_6) being connected to the first main electrode of the second transistor (T_2); the first main electrode of the fifth transistor (T_5) and the first main electrode of the sixth transistor (T_6) being connected to a second node (22) to receive a bias current; the second main electrode of the fifth transistor (T_5) being connected to the first main electrode of th second transistor (T_2) and the second main electrode of the sixth transistor (T_6) being connected to the first main

electrode of the first transistor (T_1), characterized in that the differential amplifier further comprises:

- a first resistor (26) connected between the control electrode of the fifth transistor (T_5) and the first main electrode of the first transistor (T_1),
- a second resistor (28) connected between the control electrode of the sixth transistor (T_6) and the first main electrode of the second transistor (T_2), and
- a capacitor (30) connected between the control electrode of the fifth transistor (T_5) and the control electrode of the sixth transistor (T_6).

2. A differential amplifier as claimed in Claim 1, characterized in that the first node (8) is connected to a first current source (10) and the second node (22) is connected to a second current source (24).

3. A differential amplifier as claimed in Claim 1, characterized in that the first node (8) and the second node (22) are connected to a common current source (36), and the dimensions of the third transistor (T_3) and the fourth transistor (T_4) are larger than or equal to the dimensions of the fifth transistor (T_5) and the sixth transistor (T_6).

4. A differential amplifier as claimed in Claim 1, characterized in that the first node (8) is coupled to a current source (36) and the second node (22) is coupled to the current source (36) *via* a third resistor (38).

5. A differential amplifier as claimed in Claim 4, characterized in that the first node (8) is coupled to the current source (36) *via* a fourth resistor (40).

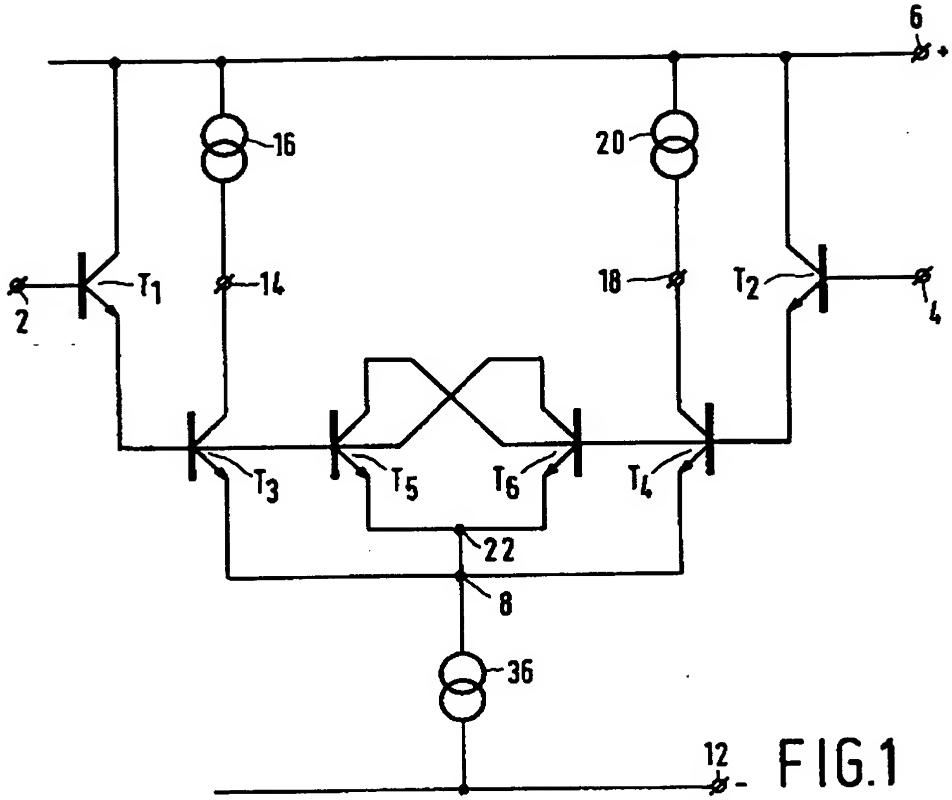


FIG.1

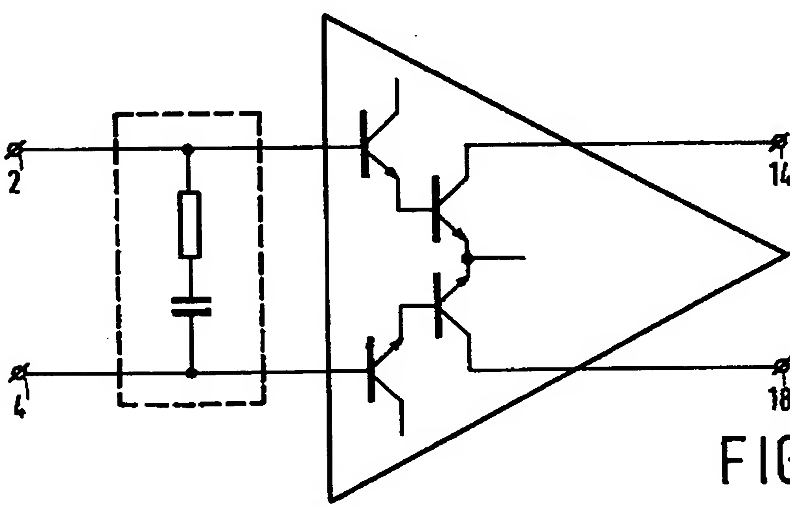
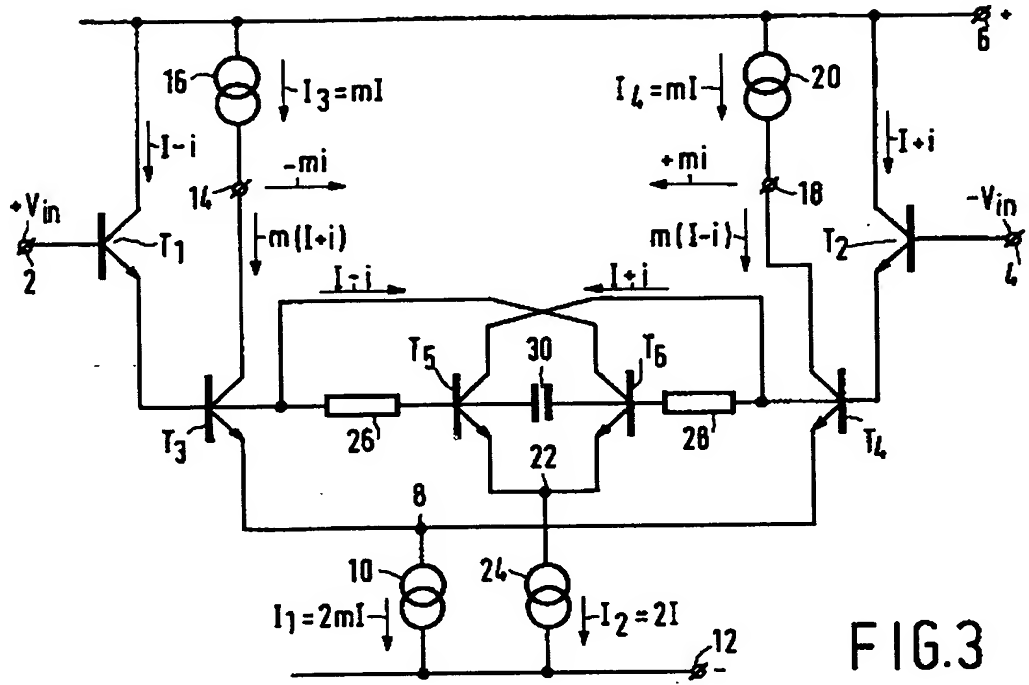
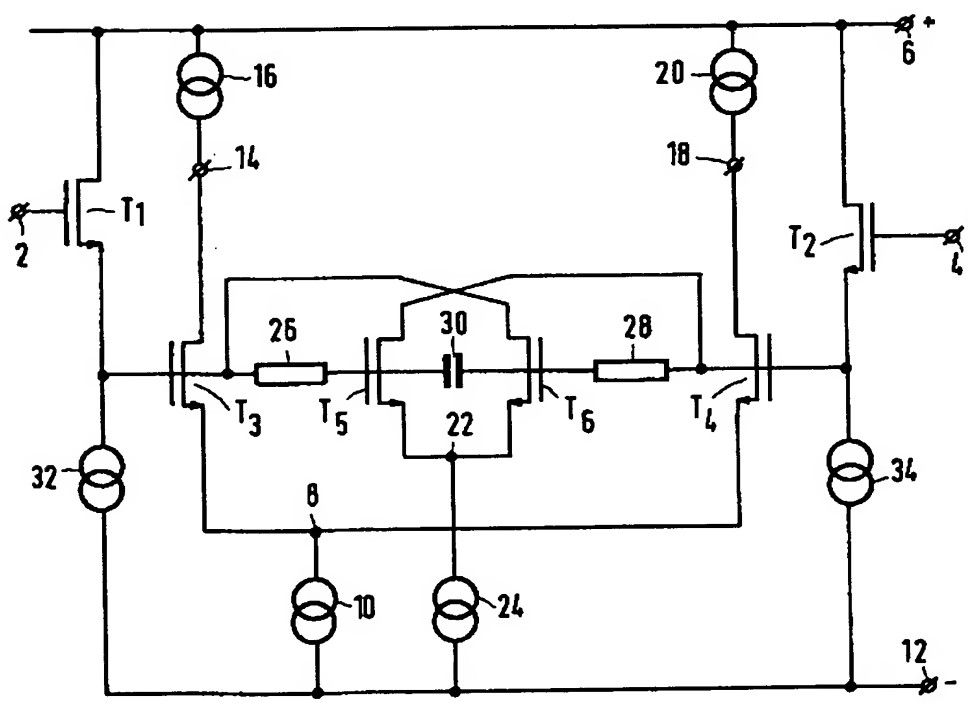


FIG.2



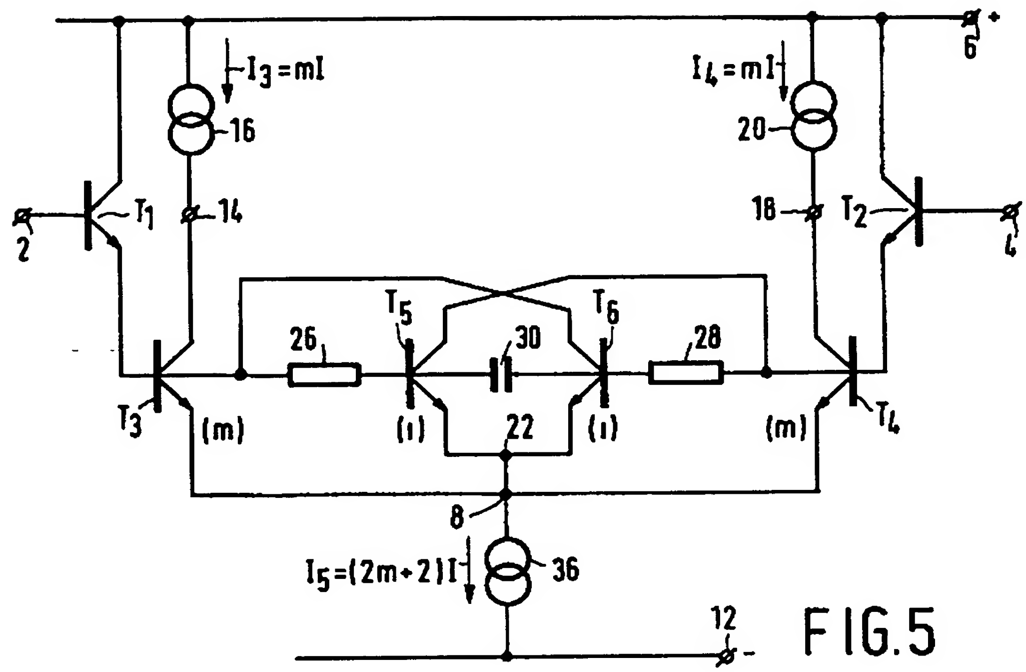
+
6
16
$I_3 = mI$
$I_4 = mI$
20
$I-i$
$I+i$
-mi
+mi
14
18
$+V_{in}$
$-V_{in}$
T_1
T_2
2
4
$m(I+i)$
$m(I-i)$
$I-i$
$I+i$
T_5
30
T_6
T_3
26
22
28
T_4
8
10
24
$I_1 = 2mI$
$I_2 = 2I$
12
-

FIG.3



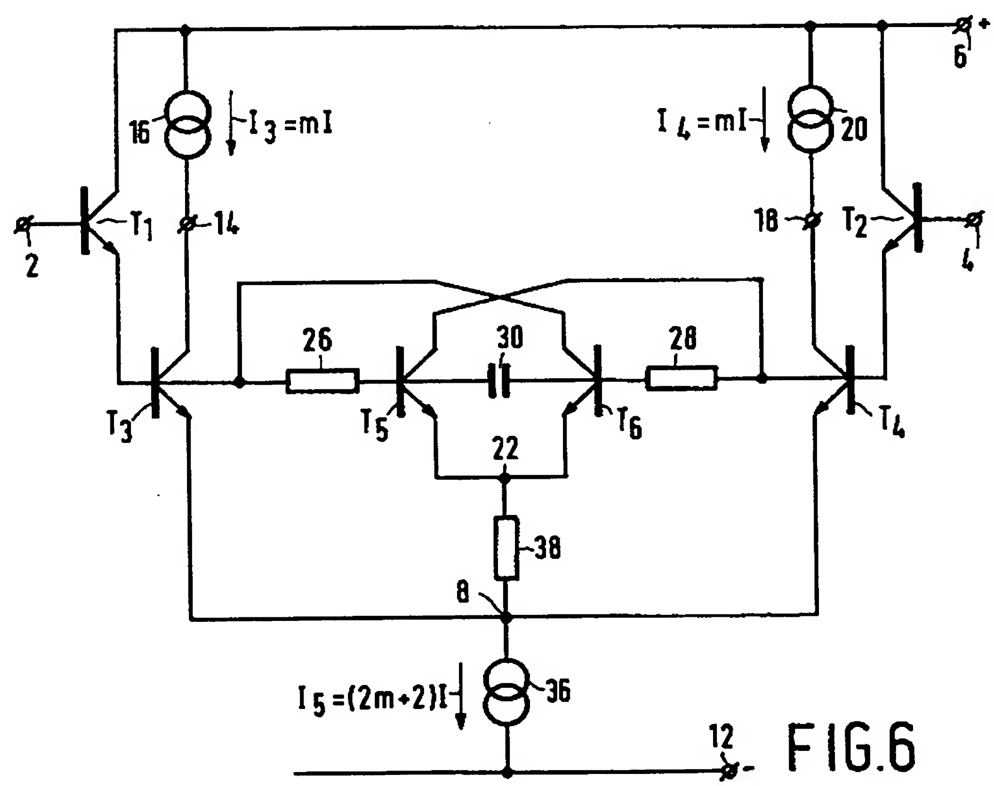
+
6
16
20
14
18
T_1
2
T_2
4
26
30
28
T_3
T_5
22
T_6
T_4
32
34
8
10
24
12
-

FIG.4



6
+
I_3=mI
16
I_4=mI
20
2
T_1
14
18
T_2
4
T_5
T_6
26
30
28
T_3
(m)
(1)
22
(1)
(m)
T_4
8
I_5=(2m+2)I
36
12
-

FIG.5



6
+
16
I_3=mI
I_4=mI
20
2
T_1
14
18
T_2
4
26
30
28
T_3
T_5
T_6
T_4
22
38
8
I_5=(2m+2)I
36
12
-

FIG.6

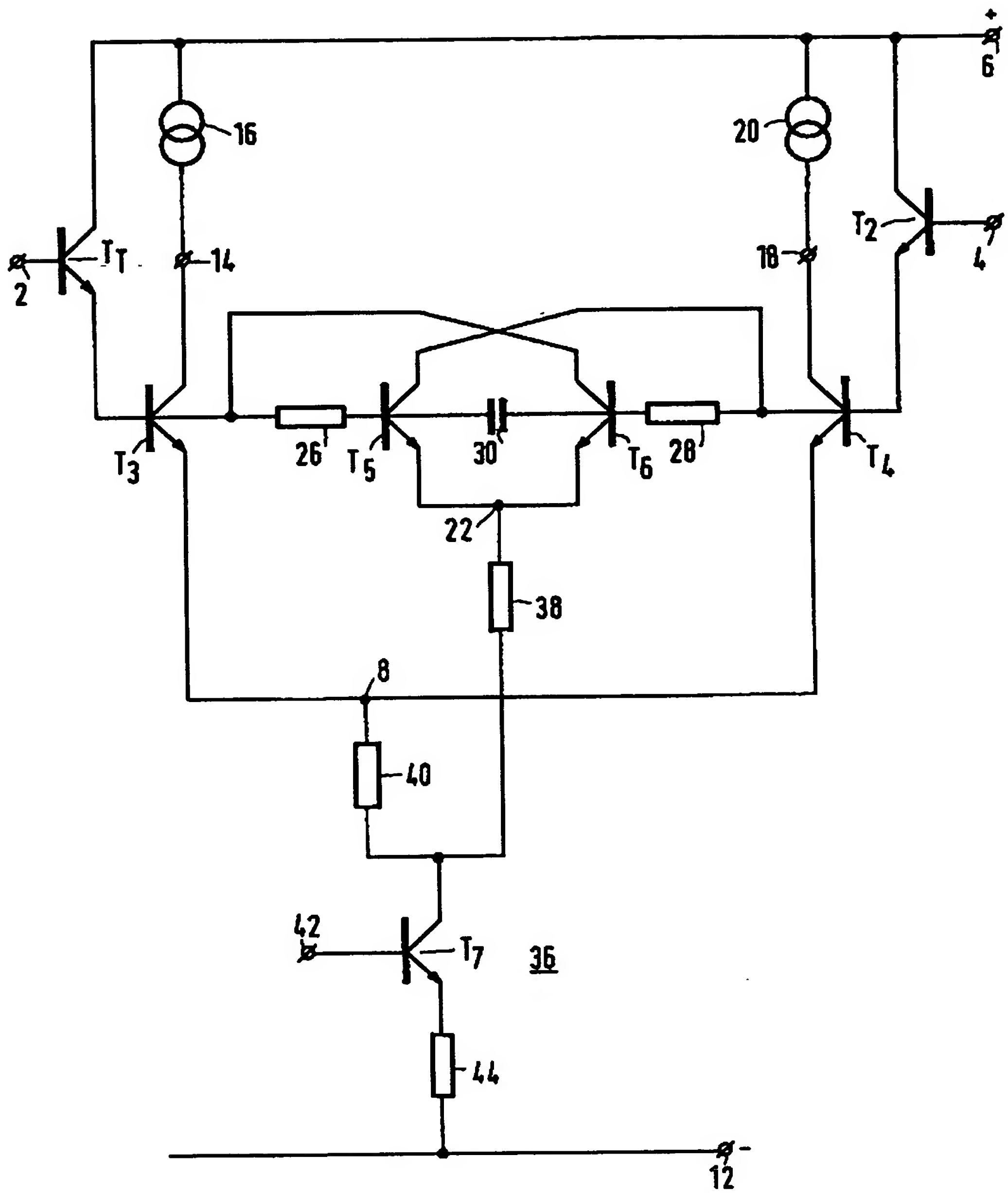


FIG.7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 20 2866

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	NL-A-8 602 892 (N.V. PHILIPS) * the whole document *	1-5	H03F1/08 H03F3/45
A	US-A-4 628 279 (D.A. NELSON) * column 4, line 5 - column 6, line 12; figures 5-7 *	1	
A	EDN ELECTRICAL DESIGN NEWS., vol.24, no.4, February 1979, NEWTON, MASSACHUSETTS US pages 93 - 94 R.A. PEASE 'IMPROVED UNITY-GAIN FOLLOWER DELIVERS FAST, STABLE RESPONSE' * page 94; figure 2 *	1	
A	JOURNAL OF THE AUDIO ENGINEERING SOCIETY, vol.30, no.11, November 1982, NEW YORK US pages 795 - 799 M.J. HAWKSFORD 'LOW-DISTORTION PROGRAMMABLE GAIN CELL USING CURRENT-STEERING CASCODE TOPOLOGY' * page 798; figure 6 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H03F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 December 1994	Tyberghien, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

PATENT SPECIFICATION

648,010

Date of Application and filing Complete Specification: July 7, 1947.

Application made in United States of America on July 5, 1946. No. 17910/47.

Complete Specification Published: Dec. 28, 1950.

Index at acceptance:—**Classes 35,** A1c3b; **and 38(v),** B1b(1:2g), B2B12.

COMPLETE SPECIFICATION

Improvements in Ignition Apparatus for Internal Combustion Engines.

We, BENDIX AVIATION CORPORATION, of 401, Bendix Drive, South Bend, Indiana, United States of America, a Corporation organised under the laws of the State of Delaware, United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The invention relates to electrical apparatus and more particularly to current distributing and circuit breaking apparatus adapted for use in ignition systems of internal combustion engines.

According to the invention, an electrical current distributing apparatus comprises a rotor carrying an electrode connected to the secondary winding of an ignition coil and periodically moved into spark gap relation with each of the output terminals of a distributor block and is characterised in that the electrode is mounted in a cup-like insulating member provided on or constituting the rotor, and that the outer periphery of the said member has a cam surface formed thereon for co-operation with a cam follower of a circuit breaker connected to the primary winding of the ignition coil.

The invention will now be described, by way of example, with reference to the accompanying drawings.

Fig. 1 is a horizontal sectional view of one form of apparatus embodying the invention;

Fig. 2 is a side elevation of said apparatus partly in section and with parts broken away, the section being taken substantially on line 2—2 of Fig. 1;

Fig. 3 is an end view looking from the right in Fig. 1 with the coil enclosing portion 11 of the casing and its contents removed; and

Fig. 4 is a diagram of the electrical circuit of said apparatus.

A single embodiment of the invention is shown in the drawings, by way of example, in the form of a small half-engine-speed magneto generator equipped with a six pole magnetic rotor and a distributor adapted for use in supplying high tension current to the spark plugs of a six cylinder engine in predetermined sequence. The embodiment illustrated comprises a single two part housing constituted by a body portion 10 and a cover portion 11. Said housing is adapted to be secured for limited angular adjustment on an engine casing (not shown) through the medium or slotted flanges 12 and suitable studs or bolts (not shown). The parts of the housing are preferably secured together by means of a channel shaped strap 13 but other suitable means may be employed. Mounted within the housing is a magnetic rotor 14 and an ignition coil 15 between which are positioned for suitable co-operation a distributor 16 and a circuit breaker mechanism 17.

The magnetic rotor construction contemplated by the invention comprises a stub shaft 18 rotatably supported by plain or roller bearings 19, in a tubular boss 20 that projects inwardly from the end wall of casing member 10. In addition to supporting said shaft for rotation, said bearings serve to limit the endwise movement or thrust of the rotor shaft. The inner enlarged end of shaft 18 is threaded at 21 and provided with a radially extending bevelled annular flange 22. Mounted on said flange and engaging the bevelled portion thereof is a ring or end plate 23 from which three or other suitable number of equally spaced pole shoes 24 project in the axial direction of the shaft.

A second set of pole shoes 25 are similar to pole shoes 24, but extend axially in the opposite direction from and alternate circumferentially with the latter. Pole shoes 25 are shown being integrally formed with a ring or end plate 26 that is mounted on a cylindrical member or sleeve 27 in engagement with a bevelled flange 28 on the latter. Said supporting cylinder or sleeve is internally threaded for co-operation with the threaded portion 21 of shaft 18 and is thereby supported in spaced relation to boss 20 of cas-

[*Price 2/-*]

ing member 10. Interposed between rings 28 and 26 of the pole shoe members and in good magnetic contact therewith is a cylindrical magnet which is axially magnetised so that pole shoes 24 and 25 are of opposite magnetic polarity, that is, all of the pole shoes 24 are of one polarity and all of the pole shoes 25 are of the opposite polarity. It will be noted that the pole shoe members and the magnet are clamped together axially between flanges 22 and 28 by threading supporting sleeve 27 on to the threaded portion 21 of shaft 18. Relative rotation of shaft 18, ring 28 and sleeve 27 may be prevented by any suitable means such as a dowel 29, and similar or other suitable means may be provided for fixing sleeve 27 and ring 26 against relative angular movement.

The pole shoes 24 and 25 co-operate in a well known manner with stator pole shoes 30 and 31, respectively which are cast into or otherwise suitably secured in housing member 10 at opposite sides of rotor 14. The ends of stator shoes 30 and 31 have abutting magnetic contact with the ends of laminated flux conducting members 32 and 33, respectively, which are similarly secured in casing member 11 and tightly embrace the core 34 of ignition coil 15. A magnetic flux path is thus completed through the windings of the coil. With the six pole rotor illustrated and the two pole stator there will be six reversals of flux through core 34 during each revolution of the rotor 14.

The distributor mechanism 16 is associated with the above described parts and comprises a moulded block or head 35 of insulating material and a combined circuit breaker cam and distributor rotor 36 consisting for the most part of moulded insulating material. Said rotor is secured directly to magnetic rotor 14 by means of a plurality of screws 37. The latter extend through elongated slots 38 (Fig. 3) in rotor member 36 to permit the latter to be angularly adjusted relative to the magnetic rotor for timing purposes. Block or head 35 has a close sliding fit into housing member 11 and fits against a shoulder 39 (Fig. 2) to serve as a closure for the coil and condenser compartment.

A plurality of circularly arranged electrodes 40 and an electrode 41 centrally disposed with respect to the others are moulded into or otherwise suitably secured in insulating block 35. Contact member or electrode 41 is permanently connected through a spring 42 with the high potential end of the secondary winding 43 of coil 15, whereas each of the electrodes 40 is connected to a terminal 44 in an insulated socket 45 of a plug and socket connector by means of a cable 46. Said sockets which may be of any suitable construction are mounted in casing member 11 for receiving known types of plug contacts which may in turn be connected with the spark plugs of the engine.

The other end of the central electrode 41 of the distributor has a brushing engagement with a spring finger 47 that is mounted on distributor rotor 36 by means of a screw 48. The latter also secures a radially projecting electrode 49 in electrical engagement with spring 47 and in spark gap relation with the stationary electrodes 40 for successive cooperation therewith during rotation of the rotor. Block 35 and rotor 36 are provided with overlapping or telescoping flanges 50 and 51, respectively, which serve to prevent any flash-overs or sparking between the distributor electrodes and the housing or other grounded conducting parts.

The outer peripheral surface of rotor 36 is provided with a suitable number of lobes 52 (six in the illustrated embodiment) that are best seen in Fig. 3, which are effective to actuate the circuit breaker mechanism 17. The latter may be of any suitable construction, but as illustrated the same comprises a spring mounted metallic cam follower 53 that is in continuous engagement with the periphery of rotor member 36, a spring mounted insulated contact 54 movable by the cam follower, and a stationary electrically grounded contact 55. The entire circuit breaker mechanism is preferably mounted on a rigid bracket 56 which is mounted for pivotal adjustment about a fixed pivot 57. The six lobes 52 provided on rotor member 36 are thus effective to cause separation and engagement of contacts 54 and 55 six times during each revolution of the magneto rotor—once for each reversal of flux through coil 15.

Parts of the illustrated device including coil 15 and a condenser 58 are held in position and insulated from one another within the compartment in cover member 11 by a suitable insulating compound 59 which is preferably solid and dry when set and yet yielding or resilient. Compounds which have been found suitable for this purpose comprise polymerised cashew nut shell or linseed oil with suitable drying agents. The compound completely fills the spaces within and around coil 15 and around the cables, condenser and terminal sockets. By thus insulating and securing these parts in position, the cost of making and assembling said parts may be materially reduced without any appreciable risk of failures in operation. The yieldability of the filling material also cushions the parts against shock and vibration.

As best seen in Fig. 2, condenser 58 has one terminal thereof grounded at 60 and the other terminal thereof connected to the insulated contact of circuit breaker 17 through the medium of a resilient connecting means 61. The latter is also connected to the primary winding 62 of the coil by a cable 63 and to the socket 64 of a grounding switch connection by means of cable 65.

In the operation of the above described structure, shaft 18, and hence, magnetic rotor 14 is driven at one-half the speed of the engine crankshaft through a suitable connection, including gear or splined member 66, to a rotating part of the engine. The rotation of the rotor creates periodic reversals of flux through coil 15 and hence generates an alternating current in the primary winding 62 in a manner which is well known to those skilled in the art. At predetermined intervals in timed relation with the rotor 14, the lobes 52 on rotor member 36 separate contacts 54, 55 of the circuit breaker thereby breaking the circuit through the primary winding. This in turn results in the induction of a high voltage current in secondary winding 48 which flows through contact members 42 and 41, spring finger 47 and electrode 49, to one of the stationary distributor electrodes 40 and in turn to a spark plug of the engine through cable 46. The apparatus may be rendered inoperative by connecting the insulated contact 54 of the circuit breaker to ground through cable 65 and a suitable grounding switch in a well known manner.

The rotation elements of the above described device may be driven in either direction. When the same are driven in a counter-clockwise direction, as viewed in Fig. 3, the spring finger 47 and electrode 49 are mounted in the position indicated. When clockwise rotation is desired, these parts may be mounted at the position indicated by numeral 66.

There is thus provided an improved magneto generator which is of light weight and yet of sturdy construction and which is extremely compact and of small size for its output capacity. Additionally, the construction embodies a distributor encased with the magneto generator in a manner whereby space is conserved without increasing the danger of failures resulting from flash-overs or sparking. The present construction also lends itself to quick and inexpensive assembly and disassembly, with all vital parts readily accessible for inspection and repair.

Although only a single embodiment of the invention is illustrated and described it will be understood that various changes may be made in the construction and arrangement of parts to suit requirements within the scope of the invention.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An electrical current distributing apparatus comprising a rotor carrying an electrode connected to the secondary winding of an ignition coil and periodically moved into spark gap relation with each of the output terminals of a distributor block, characterised in that the electrode is mounted in a cup-like insulating member provided on or constituting the rotor, and that the outer periphery of the said member has a cam surface formed thereon for co-operation with a cam follower of a circuit breaker connected to the primary winding of the ignition coil.

2. An apparatus as claimed in Claim 1, characterised in that the cup-like insulating member co-operates with the distributor block the block having a circular flange projecting within the cup-like member.

3. An apparatus as claimed in Claim 2, wherein the output terminals extend along the inner wall of the flange provided on the distributor block.

4. An apparatus as claimed in any of Claims 1, 2 or 3, having a casing formed with an internal hollow boss rotatably supporting the shaft of the rotor, which shaft extends therethrough.

5. An apparatus as claimed in any of Claims 1-3, comprising a magnetic flux distributing rotor adapted to energise the ignition coil, the said magnetic rotor and the cup-like member being mounted on a driving shaft.

6. An apparatus as claimed in Claim 5, in which the magnetic flux distributing rotor is formed with a cylindrical magnet through the bore of which extends the shaft of the rotor.

7. An apparatus as claimed in Claim 6, wherein the cylindrical magnet is kept in engagement at its opposite ends with a pair of end plates formed with a plurality of pole shoe members spaced about the magnet and extending axially in opposite direction from said end plates.

8. An apparatus as claimed in any of Claims 5-7, comprising a two-part casing, one part of which encloses the rotor and the cup-like insulating member and the other part of which encloses the ignition coil.

9. An apparatus as claimed in Claim 8, wherein the distributor block is adapted to shut off one part of the casing from the other.

10. An apparatus as claimed in Claim 8, comprising a plurality of stator pole shoes mounted in one part of the casing and a plurality of bars mounted in the other part of said casing in end-to-end relation with the stator pole shoes to co-operate with the magnetic rotor on the one hand and with a core extending through the ignition coil on the other hand.

11. An apparatus as claimed in Claim 10, wherein the axis of the core extends at right-angles to the axis of the rotor.

12. An apparatus as claimed in any of Claims 9, 10, or 11, comprising a condenser loosely mounted in the casing and elements electrically connected to the ignition coil and the condenser and extending through the dis-

tributor block said block shutting off in said casing a compartment filled with a solid insulating means around the coil, condenser and said elements.

18. An electrical current distributing apparatus substantially as described and as illustrated with reference to the accompanying drawings.

Dated this 7th day of July, 1947.

For the Applicants,
F. J. CLEVELAND & COMPANY,
Chartered Patent Agents,
29, Southampton Buildings, Chancery Lane,
London, W.C.2.

Printed for His Majesty's Stationery Office by Wickes & Andrews, Ltd., E.C.4. 89/244.—1950.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies, price 2s. 0d. each (inland), 2s. 1d. (abroad) may be obtained.

[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1

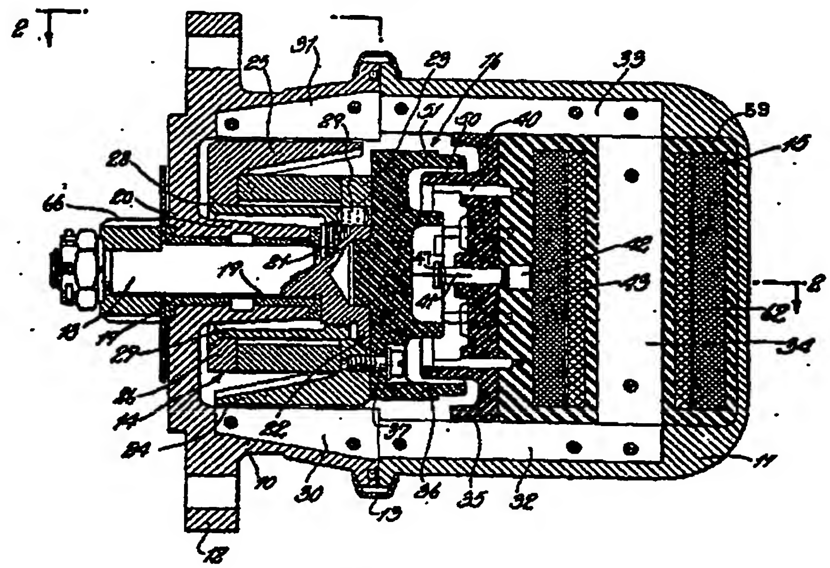
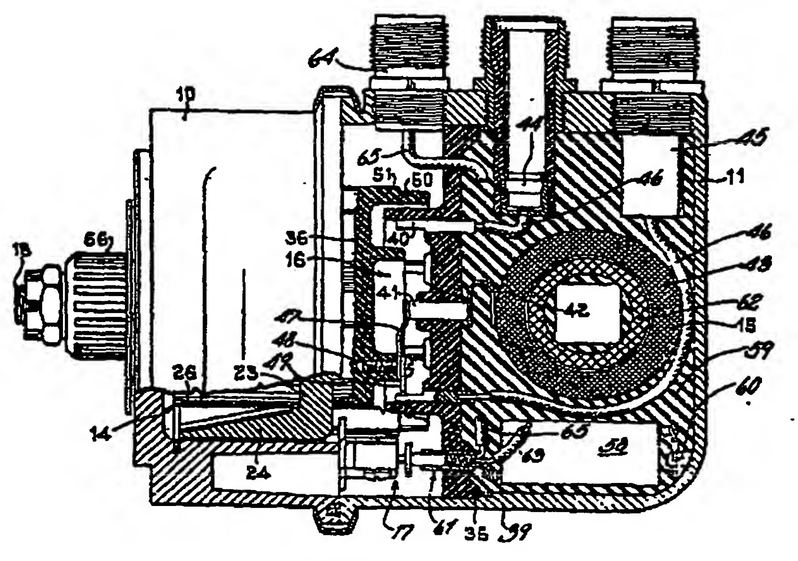


Fig. 2



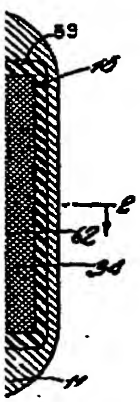
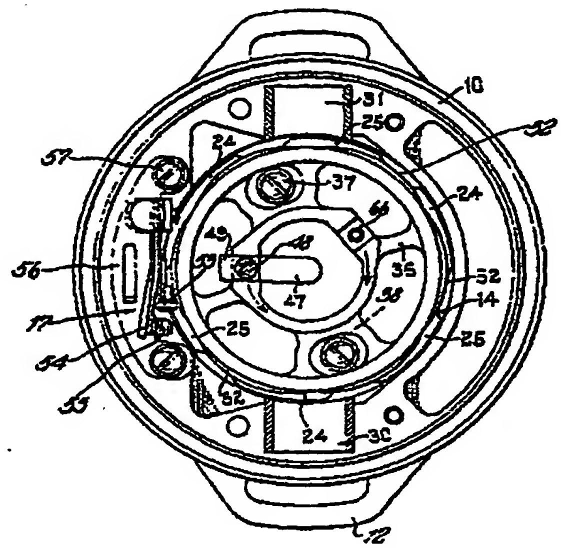

59
15
2
62
34
11

Fig. 3


10
31
25
32
57
24
37
44
49
48
56
39
35
52
14
47
38
17
25
54
53
52
24
30
12

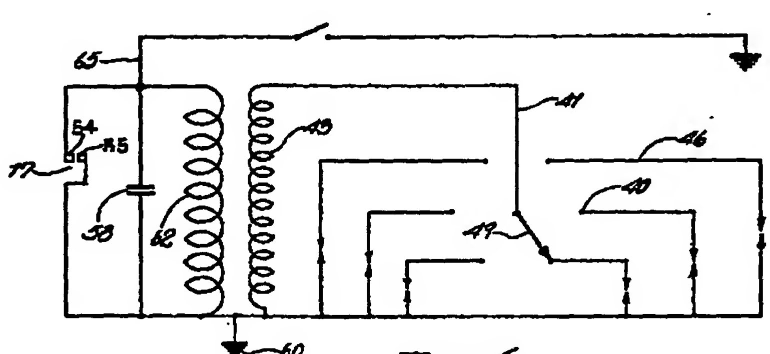

65
41
54
55
45
46
17
40
58
62
47
60

Fig. 4.

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1

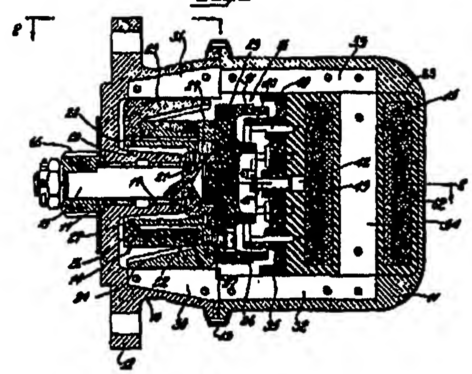


Fig. 2

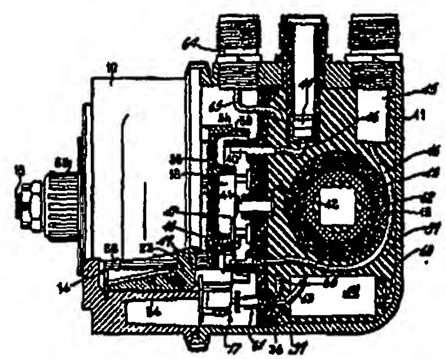
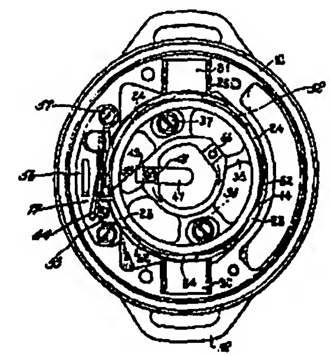


Fig. 3



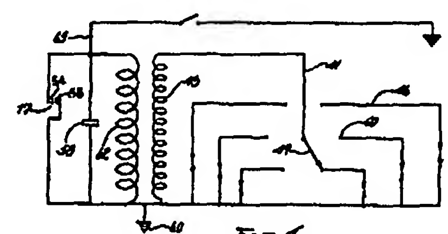


Fig. 4